◆ Analysis of the Tropical Tropopause Layer using the global nonhydrostatic atmospheric model

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Introduction

Purpose of this study is to understand the effective processes with small to planetary scales controlling the TTL dynamics and dehydration using the **'global'** and **'nonhydrostatic'** cloud resolving atmospheric model, **NICAM**.

various dynamical processes
- convection [> 7.0 km]
- organized convection [planetary scale]
- gravity waves
- equatorial Kelvin waves

Topics …

1. General Characteristic of the Model Simulations.
2. The Regional Characteristics of Deep Convective Activity
3. Temperature Variations in the TTL
   - Regional Characteristics
   - Kelvin Waves and MJO
   - Tropical Cyclone

NICAM

[Nonhydrostatic ICosahedral Atmospheric Model]
Explicit W calc.; No cumulus parameterization.
Cloud microphysical scheme : (Grabowski, 1998)

- Horizontal spacing : 7.0km
  Vertical spacing : 1.4 km in the upper troposphere.
- Initial condition: derived from NCEP Global Tropospheric Analysis data
- Integration : performed over 32 days, starting at 0000 UTC on 15 and December 2006 (No nudging during the integration)
- SST : SST was interpolated from the weekly mean data of the Reynolds SST data set

Observational Data

Various observational data were used to evaluate the results from the NICAM model simulations

- Daily OLR data from (NOAA) polar–orbit satellites with a 2.5 grid horizontal spacing
- Half-hourly infrared brightness temperature (Tbb) data from IR channels loaded on five geostationary satellites
- NCEP/NCAR reanalysis data (NCEP1) (4 times per day, 2.5 by 2.5 horizontal resolution)

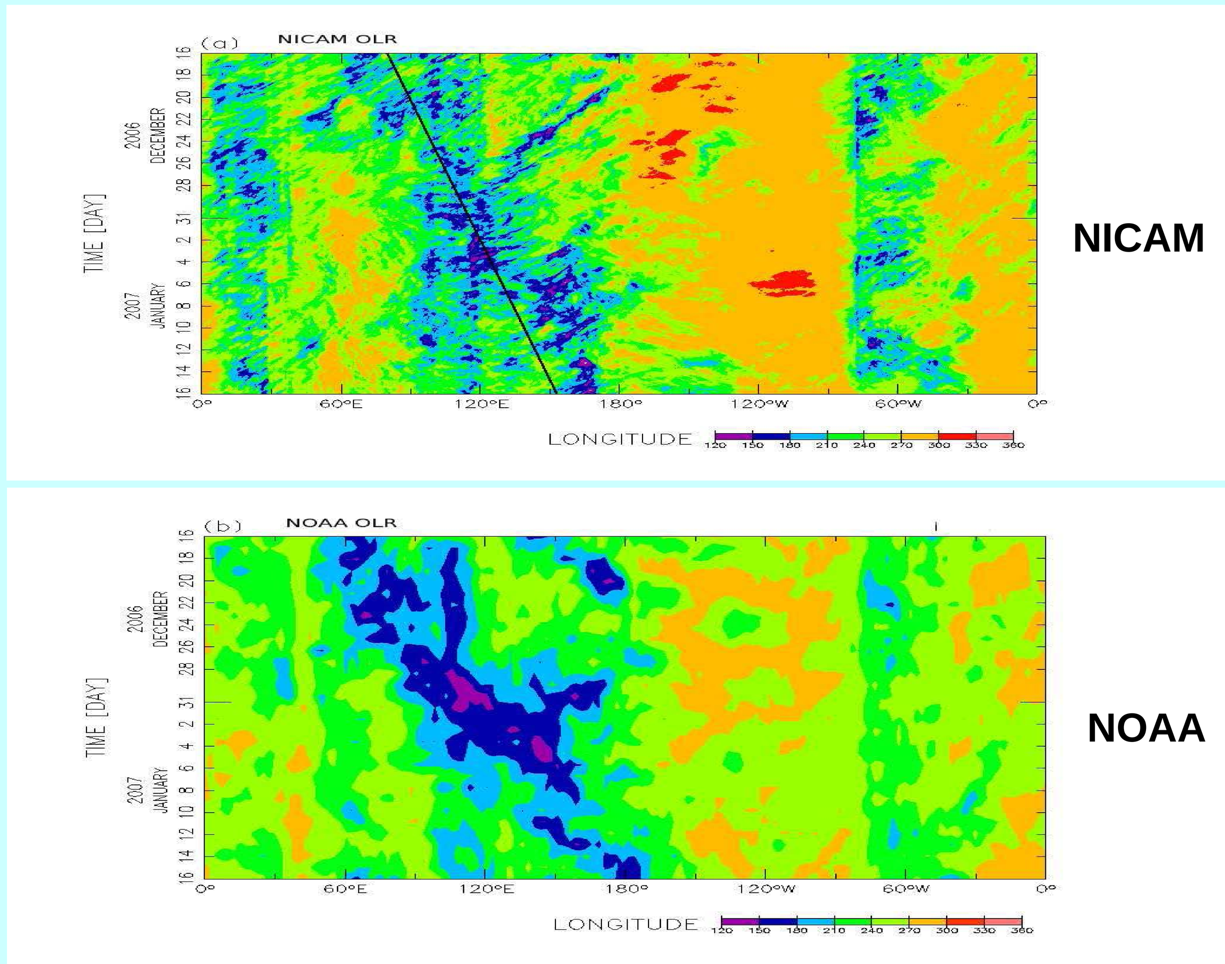
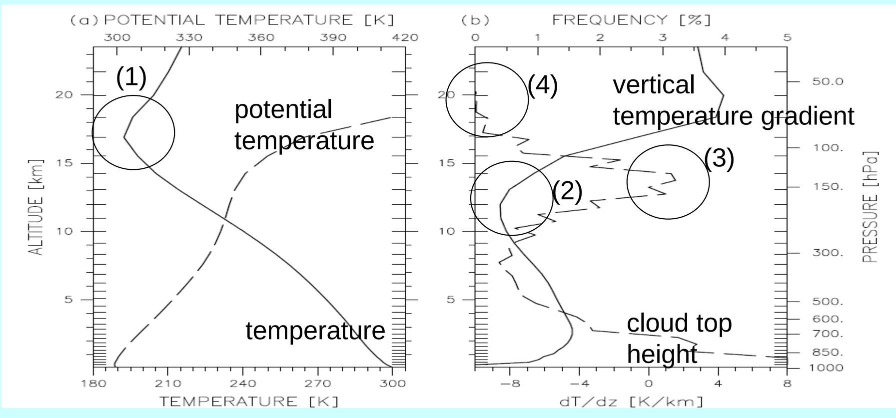


Figure 1. Longitude - time distribution of OLR averaged between 5S and 5N

Phase speed and horizontal scale of MJO are well simulated.

Cloud is defined by cloud (ice + water)+ snow + rain > 0.01g/kg

1. General Characteristics of the Model Simulations



(1) CPT -> 191.5 K and 16.9 km
(2) lapse-rate tropopause -> 194.0 K and 16.5 km.
(3) local maximum in cloud top height frequency, at 13–16 km, corresponding to the level of maximum convective outflow.
(4) The proportion of overshooting is 0.53%. This frequency generally agrees with the 0.34% obtained from satellite GRAS ICESAT data in the tropics by *Dessler et al.* [2006]

Figure 2. Average vertical distributions of (a) temperature (solid curve) and potential temperature (dashed curve) and (b) vertical temperature gradient (solid curve) and the frequency of cloud top height (dashed curve) for the region 10°S -10°N.

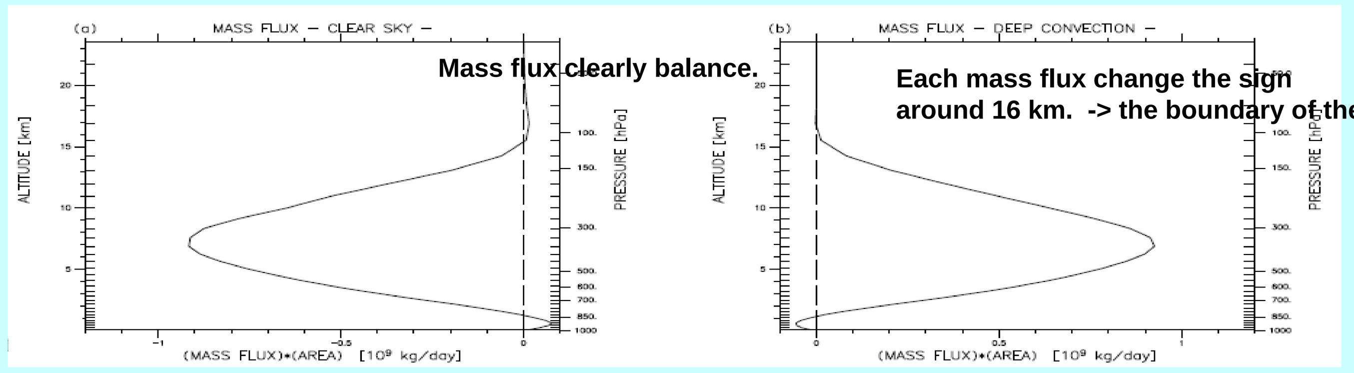


Figure 3. Vertical profiles of mass flux multiplied by area for (a) clear-sky regions and (b) deep convective regions between 30°S and 30°N. Deep convective regions are defined as grid points for which the cloud top is above 13 km and the cloud bottom is below 2.0 km.

2. The Regional Characteristics of Deep Convective Activity

We define deep convective regions as grid points where the height of the cloud top is above 16 km, and the cloud base is within 2 km of the surface

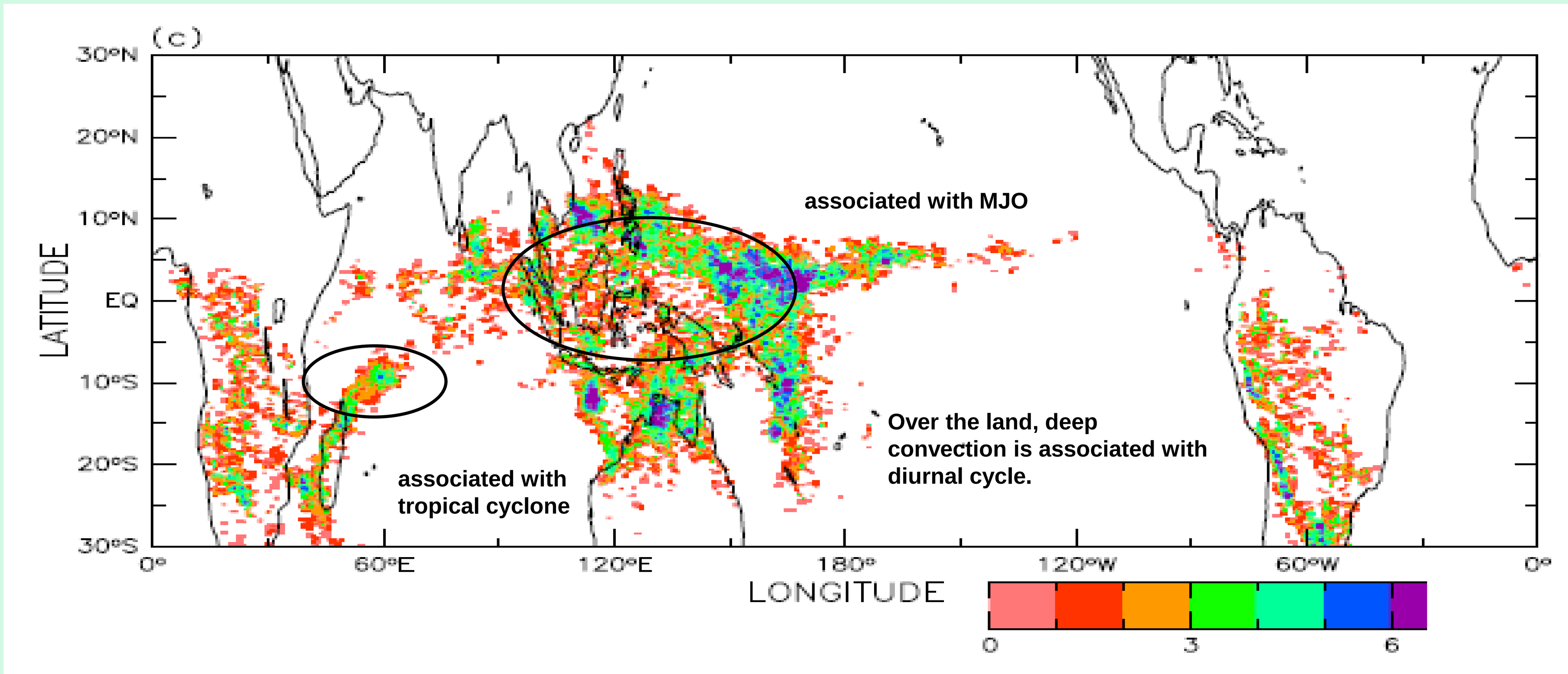


Figure 4. Horizontal distribution of deep convective frequency (expressed as a percentage)

3.1 The Regional Characteristics of Tropopause Temperature Variation

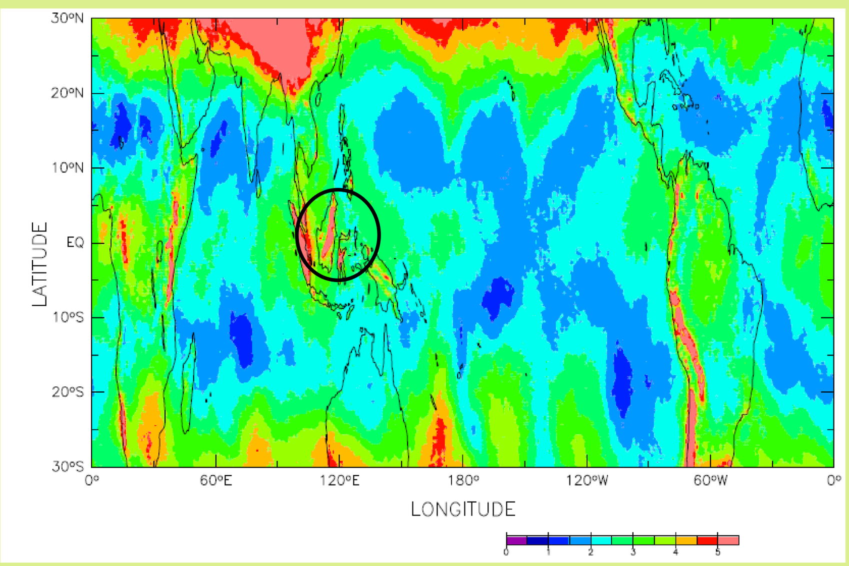


Figure 5. Horizontal distributions of the standard deviation of temperature at 16.9 km

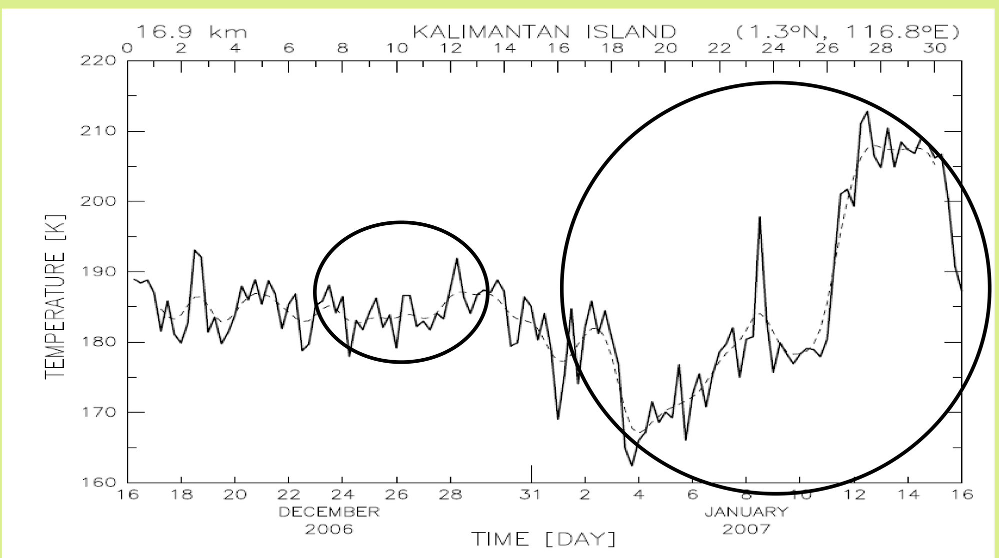
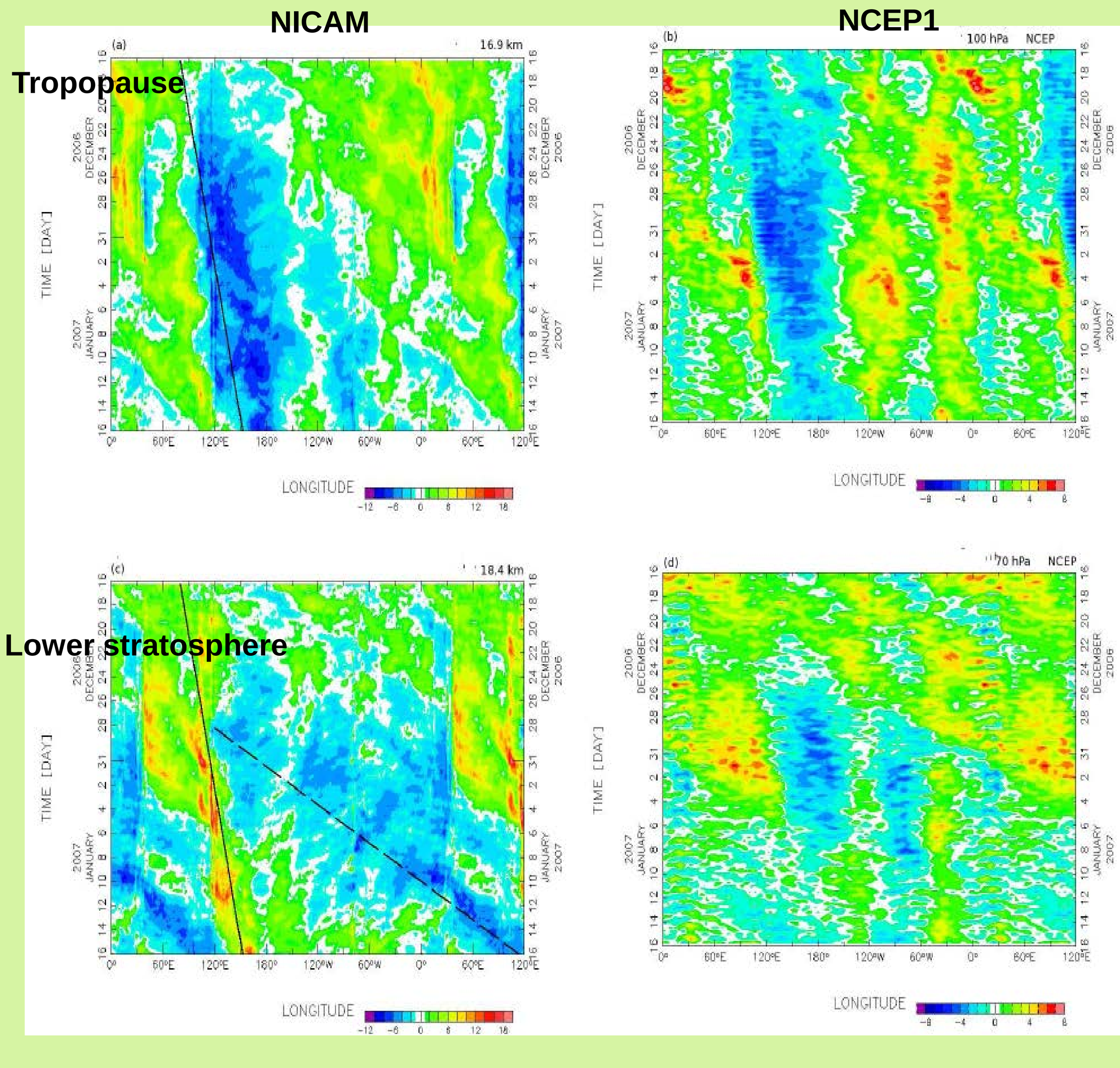


Figure 6. Time series of temperature at 16.9 km at Kalimantan (1.3°N,116.8°E). Dotted curve shows a 2-day running average.

- diurnal cycle -> 10 K.
- Low temperatures occur between 31 December 2006 and 10 January 2007. That have an amplitude of up to 20 K

3.2 Equatorial Kelvin Waves and MJO



The zonal-time averaged temperatures at 16.9 and 18.4 km are 192.2 K and 196.0 K

NICAM well simulates the eastward propagating signals In UTLS. These signals are associated with MJO convection.

A quadratic phase difference is clearly seen between the temperature and zonal wind fields around the Tropopause (not shown).

Using the wave parameters, we confirmed that the slow eastward-propagating signal can be regarded as equatorial Kelvin waves with a strong easterly background flow. The temperature amplitude of ~20 K is associated with Kelvin waves.

Figure 7. Longitude-time distributions of the temperature anomaly.

3.3 Tropical Cyclone

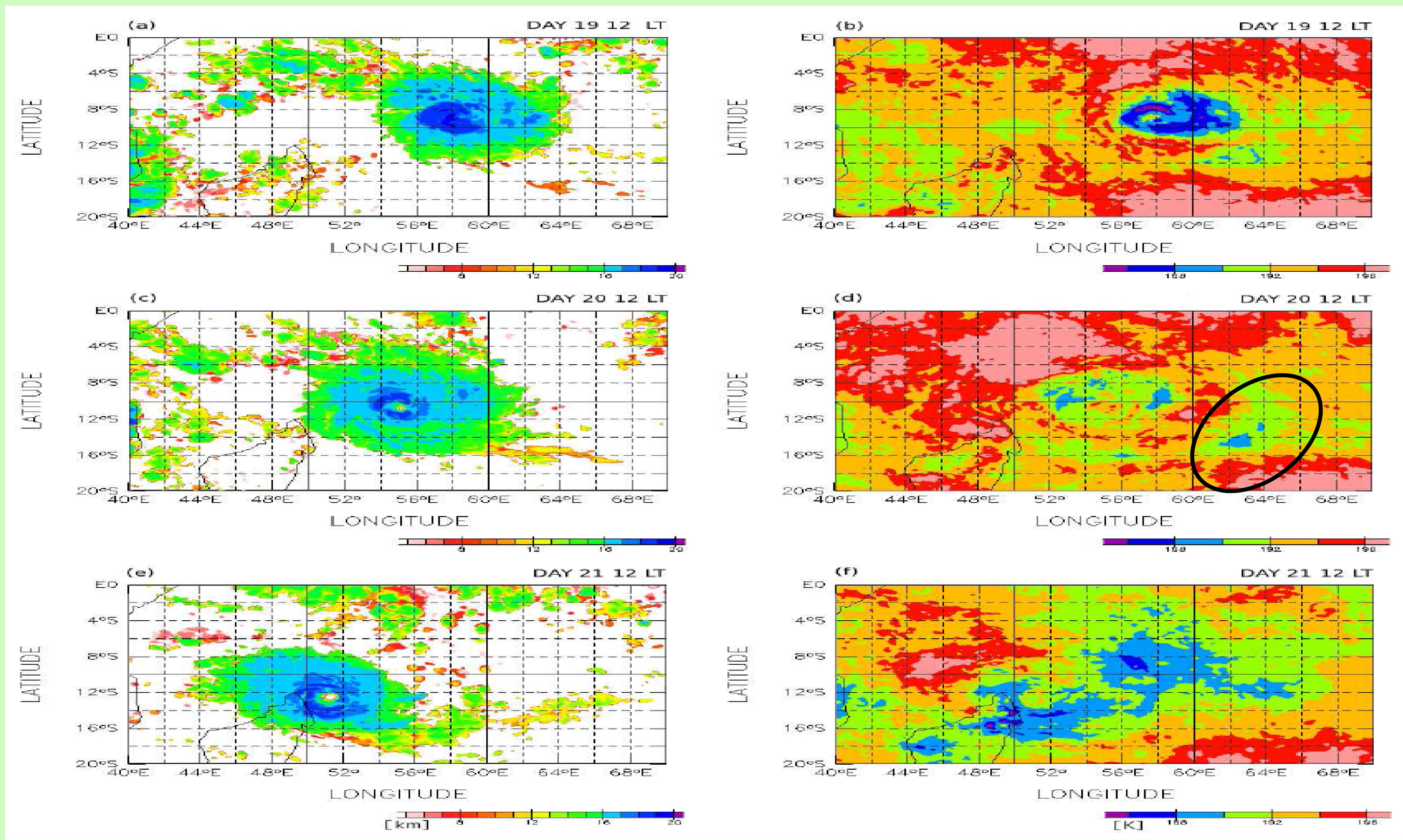


Figure 8. Horizontal distributions of cloud top height (a, c, e) and temperature at 16.9 km (b, d, f) over tropical cyclone Bond a t 12 LT on 19, 20, and 21 December 2006.

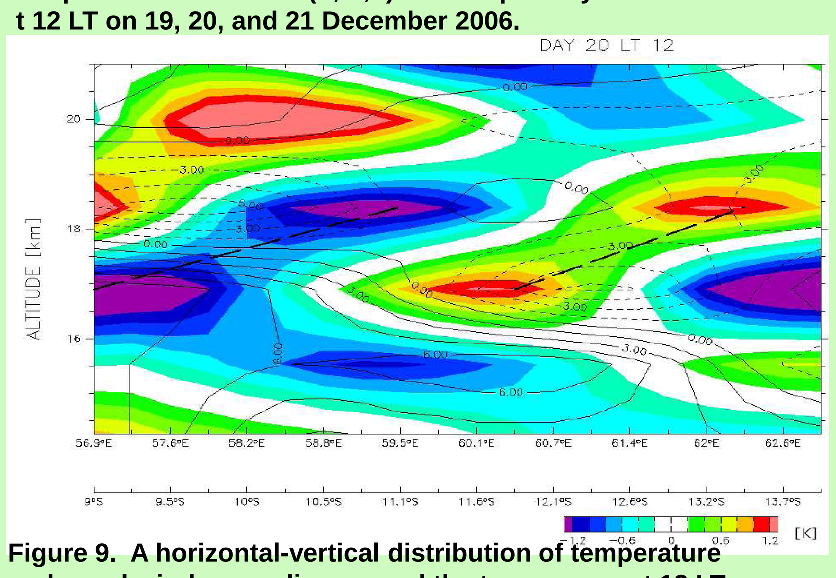


Figure 9. A horizontal-vertical distribution of temperature and zonal wind anomalies around the tropopause at 12 LT on 20 December 2006.

The center of tropical cyclone Bond was observed at 9°S, 58°E on 19 December 2006.

Bond weakened after 22 December.

On 19 December, low temperatures of less than 190 K (192.3 K for 10°S–10°N average) were observed over the core of Bond. The temperature was as low as 184.1 K. The zonal extent of the low temperature region of less than 190 K was 500 km. After 20 December, the low temperature region tended to be dissipated and spread. This was caused by the propagation of gravity waves excited by tropical cyclone Bond

gravity waves with a horizontal wavelength of 600 km. The vertical wavelength was estimated to be 3 km. The amplitude of the temperature and zonal wind components is 1.9 K, 6 m s^{-1}.

Summary

We investigate the role of the deep convection in the TTL using the Nonhydrostatic Atmospheric Model NICAM.

- General characteristics such as the zonal mean fields, average profiles, and large-scale convective patterns (including the MJO activity) were found to agree reasonably well with the atmospheric observations. (For reference, Fig. 1, 2, 3)
- Over land, deep convective clouds show clear diurnal variations and are most often observed in the local evening. Over the ocean, deep convective clouds are found over the ITCZ, SPCZ, and in the vicinity of large islands in Indonesia, and are mainly associated with transient disturbances such as tropical cyclones and the MJO (For reference, Fig. 4)
- The NICAM simulated multi-scale clouds well; i.e., diurnal variations, tropical cyclones (mesoscale), and the MJO (global scale), were all as observed in the real atmosphere. (For reference, Fig. 1, 4)
- Diurnal variations of tropopause temperature with an amplitude of 10 K were found over the Indonesian maritime continent. (For reference, Fig. 6)
- These diurnal variations are superimposed on large, low-frequency temperature variations associated with Kelvin waves, which have an amplitude of 20 K. (For reference, Fig. 6, 7)
- Low temperature regions in Bond were caused not only by deep convection, but also by gravity waves generated by the tropical cyclone. The temperature drop associated with deep convection was up to 6 K, and covered a horizontal extent of 500 km, while the drop associated with gravity waves reached 2 K, with a horizontal extent of 1000 km. (For reference, Fig. 8, 9)
- These results are published in Kubokawa et al. 2012 (JGR, VOL. 117, D17114, doi:10.1029/2012JD017737, 2012).